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CHANGES IN MONTHLY WEATHER REVIEW CHARTS AND SECTIONS.

Beginning with this issue four small inset charts will appear, one each on charts Nos. II, III, V, and VIII. The inset chart on No. II will give the departure of the monthly mean pressure from the normal; the inset on No. III will give the average change in pressure, increase or decrease, between the current and preceding months; the inset on chart No. V will show the departure of precipitation from the normal; the inset on chart No. VIII will show the depth of snow on the ground at end of month.

Changes in titles on Charts II and III are the adoption of the terms anticyclones and cyclones for HIGHS and LOWS, respectively. Chart No. IV will show departure of data for Canadian stations regularly hereafter, although owing to difficulties in transmission of mail reports from some of the most distant of those stations it may happen that the data may not always be complete for any given month.

In addition to the changes in charts, there is to be a monthly discussion of aerological conditions by Mr. W. R. Gregg. This discussion will appear in the section on "Weather of the Month" and will follow "Cyclones and Anticyclones." Mr. Gregg's section is to be known as "Free-air conditions."—EDITOR.

THE WEATHER ELEMENT IN RAILROADING.[1]

By GUY H. BURNHAM.

[Clark University, Worcester, Mass. Jan. 31, 1922.]

SYNOPSIS.

Railroading in every clime has important weather problems to meet and overcome, for trains and tracks have no protection against the various elements of nature. First of all, temperature extremes have a racking effect upon all steel and iron work. Rails and car wheels, exposed to such severe meteorological conditions, often break and delays sometimes result. To overcome these troubles, steel made by the open-hearth process is being used with good results.

Of the various forms of precipitation snow is regarded as the great enemy of rail transportation. Each year millions of dollars are spent in fighting the battle against snow, for windbreaks of various sorts must be erected, snowplows of different types manned and equipped, and miles of snowsheds constructed. Heavy rains bring about floods which wash away bridges, undermine roadbeds, and cause landslides. Abundant rainfall also produces luxuriant vegetation, which is a great nuisance on earth ballasted roads; for, unless cleared from the tracks, train operation is rendered difficult. Moisture also greatly reduces the life of ties and other woodwork; and to combat this effect, expensive preservative processes have to be introduced. Sleet storms and thundershowers often put electrified lines out of commission and thus create problems for the electrical engineer to solve.

Wind is an important factor in railroading, for trains are sometimes derailed by high winds. Snow and sand impelled by strong winds drift on the track, often delay transportation, and bring many difficult problems for railroad engineers to solve.

The weather affects not only the track and rolling stock of the railroad, but also the goods which it transports. This is especially true of the transportation of perishable goods in which temperature is the all-controlling factor. To regulate properly the temperature of perishable goods in transit, precooling and icing stations have been built and refrigerator and heater cars have been invented. To the efficiency of these various agencies we owe the safe transportation of many of our staple food products.

INTRODUCTION.

To the railroad man, the various phases of the weather—the rain, the sleet, the snow, the hot days, the cold days—have a significant meaning, for each brings with it special problems which have to be met and overcome. Upon the solution of these problems much depends, for the railroad is such an indispensable agent in modern life that its service must be kept up to the highest possible efficiency. In the olden days our forefathers procured life's necessities in the communities in which they lived—the town gristmill supplied the flour; clothes for the family were the product of the spinning wheel, and shoes were made from hides tanned at home. The primitive community thus was able to take care of its ordinary wants; and because of the poor means of communication then existing, but little intercourse was carried on with the outside world. As time went on roads were built between the various communities, canals were dug, rivers widened, commerce began to spring up, and the horizon of man broadened somewhat. The greatest developments along this line, however, have occurred within the last hundred years and have been mainly due to two agencies of transportation—the steamship and the railroad. To-day we look to distant lands for the sources of raw material for our factories and we talk of world markets for our goods, all of which would seem like a dream to our ancestors and which would be impossible had it not been for the application of steam as a propelling agency to land and water transportation. These two modes of transportation are now found in all parts of the world and hence the varied weather conditions which they have to face have far-reaching economic results. The problems connected with water transportation while very interesting are not so complex as those related to railroading and hence we shall confine our discussion entirely to the latter in this paper.

Although railroads are found in nearly every clime from the frozen plains of the north to the tropical jungle, their greatest developments have been reached in the temperate zones. The building of these roads, now largely a matter of history, gives us many a heroic tale of how mighty rivers were bridged, towering mountains overcome, and huge forests penetrated. To-day the story of railroading is largely one of a battle against the elements of nature to

[1] Thesis submitted in course on meteorology at Clark University.

keep the roads running—heavy rains wash away bridges, ballast, and track; rot ties and cause landslides; drifting sand dunes often interrupt the service; snow blocks the tracks and prevents the operation of trains; sleet often puts electrified lines out of commission; and extremes of heat and cold not only raise havoc with the rails and locomotives but also do considerable damage, unless precautionary measures are taken, to perishable goods in transit.

Our problem then naturally divides itself into two parts—the effects of the weather upon the roadbed and rolling stock and its effects upon the goods transported. We shall now discuss each in detail.

THE WEATHER ELEMENTS IN MAINTENANCE OF WAY AND ROLLING-STOCK PROBLEMS.

In railroading man has to furnish not only the vehicle but also the highway; and since both have to withstand the attacks of nature, the railroader finds himself constantly facing many problems that never appear to those engaged in other lines of transportation. The solution of these problems, which entail upon the railroads large upkeep costs, becomes largely a struggle against the various weather elements. The story of this battle as we shall soon see is very interesting.

Temperature is an important element in railroading. Extremes of heat and cold have a racking effect upon rails, girders, and other ironwork and careful allowances have to be made for this factor. Since steel when heated tends to expand, most railroads have track regulations which require foremen to pay particular attention to this element, the allowance to be made depending upon the season of the year in which the rails are laid. All track manuals have tables which provide for allowances of $\frac{5}{16}$ of an inch during coldest weather; $\frac{1}{8}$ of an inch during spring and fall, and $\frac{1}{16}$ of an inch during the hot summer months.[2] Such general rules as this have been evolved as a guide because of the difficulty of determining the real temperature of the rail when laid. When followed, good results are obtained and buckling due to expansion rarely occurs. In bridge construction, engineers have to make similar allowances, the girders never being solidly embedded in the concrete abutments.

The racking effects of temperature upon rails are further brought out by the large breakages which often occur during the winter season. Commenting upon this point, Dr. P. H. Dudley, of the New York Central lines, says: "The winter of November, 1911–12, had deficiency temperatures and the rails contracted in the splice bars. December had excess temperatures and the rails re-expanded partially in the splice bars. The cold wave commenced one or two days in the last of December but January was cold and in most places February and March. In that winter the railroads had the greatest epidemic of broken Bessemer steel rails, with 0.10 phosphorous that they ever experienced.[3] Such great breakages due to the large phosphorus content of the Bessemer steel and the severe meteorological conditions caused the railroads to turn to rails made by the open-hearth process. Time has proven that these rails with their low phosphorus content of 0.03 on the average stand up better than the Bessemer type under severe temperature conditions. To quote Dr. Dudley again "The winter of 1917–18 was cold but the breakages due to the cold wave in the basic open-hearth rails were not one-twentieth that they were in the winter of 1911–12." But few breakages in the same type of rail occurred in the severe winter of 1919–20 and Dr. Dudley has come to believe that these rails will stand under the heavy traffic of the New York Central lines cold waves of 40° below zero with hardly any rails breaking.

The good results obtained with the rails also led to the making of solid steel car wheels by the same method. Defects and breakages were thereby lessened and tests have proven that these wheels can withstand the severe meteorological conditions to which they are put better than any wheels previously made.

Authorities upon this subject seem to be agreed that while the open-hearth process is a more expensive way of making steel, the product is better able to endure the severe temperatures to which it is subjected. Hence we find rails and car wheels made in this way replacing those made by the Bessemer process. By following this replacement plan the railroads believe that they will be better equipped to combat the effects of that all important weather element—temperature.

The combination of a cold wave and a defective car wheel causes many rail breakages. Haines says on this point: "During the severe winter weather in January and February, 1912, many rails on lines in the Northwest were broken by flat wheels. On a line in Minnesota a 4-inch flat spot on a rolled steel wheel in passenger service broke nine 80-pound rails in a distance of 3 miles."[4] Thus rails that ordinarily would withstand severe temperatures succumb to the strain resulting from the above conditions. Railroads are spending thousands of dollars annually in maintaining an efficient inspection service in an effort to overcome this difficulty.

Low temperatures combined with moisture in a dirt roadbed form ice which heaves the track and causes rails to spread. A crushed stone ballast does away with these troubles. Besides overcoming the ice dangers, it also forms a dustless roadbed which is of decided advantage in dry weather. Up-to-date lines have ballasted miles of their roadbed in this expensive fashion and have thus been able to operate their trains in a more efficient manner.

It has also been found that low temperatures tend to double the rolling friction of freight and passenger trains. This, together with the increased head resistance which is due to the greater density of the cold air, furnishes the chief reason why train tonnage must be cut down in the winter. Thus these factors along with the trouble of making steam in cold weather explain why heavy trains often have great difficulties in starting out of stations during the cold months of the year.

Precipitation in its varied forms is probably the most important weather element with which the railroad man has to contend. In the United States snow is particularly hostile to rail transportation and various methods have been devised by the railroads to combat it. The problem of handling snow becomes more difficult when wind enters in as a factor, for the snow, impelled by the high wind, piles up in huge drifts. "Bucking the drifts" is a great winter pastime among the railroad men of the United States. To overcome the evils of drifting snow, the railroads in many parts of the country put up each autumn wooden fences in the fields along their right of ways where drifts are likely to occur. These fences are usually from 4 to 6 feet high and consist of boards nailed 3 or 4 inches apart on heavy wooden posts. They

[2] For complete table see F. J. Prior: "Construction and Maintenance of Railway Road bed and Track," Appendix F, p. 562.

[3] Information furnished by Dr. P. H. Dudley, consulting engineer rails, tires and structural steel, New York Central lines.

[4] H. S. Haines, Efficient Railway Operation, Appendix 5, p. 569.

serve as a very efficient barrier to snow driven along by high winds for "by breaking the force of the wind near the ground it causes the snow to be precipitated in a drift on the leeward side of the fence, leaving the track beyond relatively clear." [5] Many miles of these structures are set up every year and as thousands of feet of lumber are used in their construction, this one item alone looms big in the annual budget of snow removal expenditures.

In an effort to reduce their snow-fighting bills, some railroads have replaced these board fences with hardy quick-growing young trees of both evergreen and deciduous varieties. To secure the best results the trees are planted about 75 feet from the track in rows about 3 feet apart. The rows are set out in staggered formation and a space of about 3 feet is left between each tree. Experiments made with the various kinds of trees show that either two rows of conifers or eight rows of deciduous trees planted in this fashion will be equally effective. By following this plan, then, a good thick hedge is secured which increases in its effectiveness as a windbreak as the years roll by. Wherever this plan has been adopted, it has worked so successfully that others have been induced to imitate it and hence we now find it being used almost exclusively by many roads in both the United States and Canada for "experience has shown that over a period of years, a snow fence of trees has a decided advantage over the old style board fence in respect to both efficiency and economy." [6]

The transcontinental lines that cross the Cascade Mountains of Washington and Oregon and the Sierra Nevadas of California have to contend with a snow problem of great magnitude. In these mountains the snow accumulates on level ground to a depth of 25 or 30 feet and drifts may be found in the canyons and gulches that are twice as deep. Here the locomotive push plow so common on the eastern roads gives way to the powerful rotary plow. This is "a very heavily constructed car, usually built of southern pine about 12 feet high. The front which cuts the snow and throws it aside looks like a giant dirt plow. On each side of the car are heavily built wings which can be let out or pulled in as desired by the application of air. When these wings are fully extended they reach out on each side about 6 feet from the body of the car. They have just the proper curvature and angle to curl the snow up and shoot it clear of a snow bank 12 or 14 feet high." [7] Thus it can be seen that in order to keep the tracks clear in this region of heaviest snowfall, such plows are an absolute necessity.

High up in the mountains even the rotaries are of no avail in keeping the iron trail open for travel and there snowsheds have been resorted to. These sheds are usually made of heavy timbers and are roofed over and serve as tunnels through which the trains may pass. They are designed to sustain snow 16 feet in depth and where that limit is reached, it is necessary to shovel the excess off by hand. In spite of their massive structure, sections of the sheds sometimes collapse and thus block transportation until the débris is cleared away. Some of the best-known snow sheds in the world are on the Overland Route of the Southern Pacific. Here it was found necessary to construct 32 miles of snowsheds in order to operate this line during the winter months. These sheds were built "at a cost of $42,000 a mile over single track and $65,000 a mile over double track. On the average $150,000 a year is spent for upkeep and renewals, the expenditure for a typical year 1914 having been $65,000 for repairs and $91,000 for renewals." [8] In wooden sheds such as these, the fire hazard is very great. This necessitates the patrolling of the sheds every minute of the day and night and the maintenance of fire-fighting trains at convenient points. As soon as a fire breaks out, the track walker telephones to the nearest fire station and a train is rushed to the scene of the conflagration. Some railroads have tried to do away with this danger from fire by erecting concrete sheds but their initial cost renders this type of construction almost prohibitive. "On the Great Northern," for example, "for 10 miles down the western slope at the end of the Cascade Tunnel, 76 per cent of the distance has been protected at a cost of nearly $1,500,000. These sheds have concrete retaining walls and a timber roof designed for a load of 1,500 pounds per square foot." [9]

Besides actually impeding traffic, snow is sometimes a costly factor in operation in that it occasionally causes destructive slides. These slides not only sweep snowsheds and track away but sometimes hurl a train to destruction. Thus "On January 22, 1916, a snowslide struck an all steel passenger train near Corea, Wash., cutting it in two and sweeping several coaches into the ravine below with the resultant loss of several lives." [10] The New York *Evening Post* of February 4, 1922, contains a dispatch from Tokyo, Japan, describing an accident, in which 110 lives were lost and numbers of persons injured when a train was struck and buried by an avalanche. Since the former accident the United States Weather Bureau has been making a study of snowslide conditions with the idea of being able to warn railroads when they are likely to occur and thus prevent such fatalities.

Snow is the enemy of transportation not only in the mountains and country districts but also in the great city terminals. Here the maze of switches, signal apparatus, and turntables becomes blocked and frozen and delays often result. Several methods are employed to thaw them out, the most common being steam, gasoline, and electric heating devices. Coal in hopper-bottom cars often arrives at destination frozen in the car. This is due to the alternate freezing and thawing of the snow on top the load. Delays and inconveniences often follow the freezing of the load, for it is very hard to get the frozen coal out of the car. To overcome all this, steaming sheds for thawing out the loads have been built in the larger terminals.[11] From the above discussion it can be seen that the battle against snow costs the railroads of the United States millions of dollars each year. Conservative estimates place these costs in an ordinary winter at between five and six millions dollars. In a severe winter it is safe to say that they would be several million more. Time will not permit us to tell the story of this costly impediment to transportation in other countries of the world, but suffice it to say that snow is a source of constant worry to the railroad man throughout the Temperate Zone.

In New England the ice storm of November, 1921, is still vivid in the minds of the railroad men. Trolley lines were, on the whole, hit the hardest as feed wires and high-tension cables fell under the weight of the masses of ice that collected upon them, and thus many lines were

[5] Snow and Railway Transportation, A. H. Palmer, Mo. WEATHER REV., Oct., 1919, p. 698.
[6] Literary Digest, Apr. 17, 1920. Article "Trees as Snow Fences," pp. 156-157.
[7] F. J. Prior, Construction and Maintenance of Railway Roadbed and Track, p. 223.
[8] Snow and Railway Transportation, A. H. Palmer, Mo. WEATHER REV., October, 1919, p. 698.
[9] H. S. Haines, Efficient Railway Operation, p. 264.
[10] Snow and Railway Transportation, A. H. Palmer, Mo. WEATHER REV., October, 1919, p. 699.
[11] Mo. WEATHER REV., March, 1919, p. 171.

put entirely out of commission. Railroad service was, however, badly disrupted and trains were hours late because their crews had to stop to remove poles and trees that were strewn across their path. The Boston & Albany Railroad tried to keep its right of way clear of these obstacles by having the tracks patrolled by wrecking crews. So many trees and poles fell, however, that they were unable to cope with the situation and it became impossible to keep the trains on schedule time. The situation was also rendered more acute by the crippling of block-signal systems and the freezing of switches and turntables. Surely this storm will long be remembered by the railroad men of New England.

Glaze raises havoc with electrified lines. These lines draw their power from either overhead-wire contacts or third-rail contacts, and when these become coated with ice, train movement is impeded and rendered almost impossible. In the overhead construction, the danger from falling wires is obvious. On western roads where rotary snowplows are used, overhead conductors and the supporting insulators are subject to a heavy bombardment of snow, ice, and refuse with possible resultant breakage. The top-contact-third-rail is the simpliest form of the third-rail type of contacts and even when guarded can not be wholly protected from snow and ice. As its lower part is only about 4 inches above the tie the danger of grounding from wet show and ashes and from flooding is very evident. This top contact arrangement was at first tried out on the electrified lines of the New York Central around New York City, but the various objections mentioned above led to its abandonment. The adoption of the undercontact rail followed. This rail is supported by insulators from brackets carried on the ties and is thus given a 9-inch clearance above the top of the tie. Glaze and snow do not seem to affect this rail very much as "very thorough tests made in connection with the New York Central work show satisfactory operation not only in sleet storms but also with the rail buried in snow." [12]. Glaze and snow when once frozen on the contacts, however, often give considerable trouble and sometimes threaten to tie up the operation of electric locomotives. To combat these effects, various methods have been devised, a favorite one being the spraying of the third rail with a chemical solution which will melt the icy coatings. Thus on the Long Island Railroad calcium chloride has done good work in this respect.[13] Experiments have been performed on various types of overhead wires with the idea of preventing the formation of glaze by keeping them above a freezing temperature, but whether or not they have been extended to the high tension circuits of electrified railroads I am unable to say. Temperature problems also have to be considered when dealing with overhead wires and the expansion and contraction of the same must be carefully provided for. The problem of the thunderstorm also furnishes food for thought. Severe thunderstorms seem to raise havoc with many electrified lines; the New Haven at times being especially hard hit. Thus with the entire electric division practically rendered useless by such storms, the New Haven can maintain its service only by falling back upon the old steam locomotive.

Such problems as the above seem to bear out the statements of Haines in his book on "Efficient Railway Operation," when he says that he believes that the electrified railroad is still largely an experiment and that many of its problems have not yet been correctly solved.[14]

Rain also does considerable damage to the railroads of the United States. This is especially true in the springtime when heavy rains together with melting ice and snow wash out gravel ballast and undermine tracks. Railroads have met this difficulty by replacing gravel ballast with crushed stone and by spending thousands of dollars for drainage systems for their right of way.

Where railroads pass through narrow cuts heavy rains often cause landslides. The writer personally remembers one such incident on the Portland division of the Boston & Maine Railroad, when traffic was blocked for several hours by a small landslide. To obviate this difficulty, the slopes of these cuts are being grassed over in an attempt to hold them in place. In some instances, also, retaining walls have been built.

The railroads in the Mississippi Basin probably suffer from excessive precipitation the most of any in the country. Heavy and frequent springtime rains often cause floods which completely demoralize the service of these roads. Thus, in 1903, service was generally disrupted by the carrying away of many railroad bridges. At Kansas City, Mo., for example, 16 out of the 17 bridges that cross the Missouri at that point were swept away. The one that remained withstood the flood only by being weighed down by 15 large locomotives which had been previously placed on the bridge.[15] Railroad tracks were generally torn to pieces by this flood, freight cars were smashed into bits, and many were carried down the river and huge locomotives were rolled over and over and were found buried several feet deep in the mud. The Missouri Pacific yards in Kansas City seemed to be the playground for the flood. Freight cars and shifting engines were scattered about, small buildings were completely wrecked, dead cattle and hogs were to be seen everywhere, as were piles of débris, which often mounted to a height of 40 feet. Thus it can be seen that the railroad property destroyed by these floods amounts to millions of dollars. This statement becomes more appalling when we look at the figures, the flood of 1913—a particularly destructive one—destroying railroad property valued at $16,168,565.[16]

Roads that pass through regions of heavy precipitation suffer greatly from weeds growing on the right of way. This is especially true in tropical countries, where "the roadway is constantly being overgrown, and men are kept at work cutting down the weeds, underbrush, and trees. This involves great expense and seriously reduces the earnings of the roads. Recently tank cars which frequently spray the right of way with a strong poison have come into use, as on the Guayaquil-Quito line in Ecuador, and on the Tehuantepec Railroad.[17] In many parts of the Temperate Zone weeds growing on the right of way of earth-ballasted roads also present some difficulties. Thus in the United States "the Union Pacific Railroad has used a gasoline weed burner, which scorches off the vegetation, and the salt water of Great Salt Lake sprinkled over the roadbed has also been found to serve well as a weed destroyer." [18]

In regions of heavy precipitation we find that the moisture has a destructive effect upon ties and other woodwork and may also be instrumental in the oxidization of

[12] *Annual Report of Smithsonian Institution*, 1907, page 144, "Electric Trunk Line Operation."—F. J. Sprague.

[13] *Electric Railway Journal*, June 19, 1920, page 1344.

[14] Haines, "Efficient Railway Operation: Sections on Electrification," pp. 25-32; 73-89.

[15] U. S. Weather Bureau Flood Service Bulletin M, The Flood of the Spring of 1903 in the Mississippi Watershed, p. 57.

[16] *Bulletin Z.* U. S. Weather Bureau, Flood and River Service, p. 42.

[17] R. DeC. Ward: *Climate*, p. 249.

[18] R. DeC. Ward: *Climate*, p. 315.

rails. In tropical and subtropical countries this seems to be very true, for there ties and trestles rot away very quickly. Thus "in Central America several bridges of Oregon pine between Escuintla and Palin were considered unsafe shortly after construction. It is said that no wood will stand in that climate; ties must be renewed every eight months and telegraph poles rot off in six months." [19]

Such frequent replacement of ties greatly increases the operating costs of the roads and has forced engineers to devise some plans to increase the life of the tie. Preservatives such as creosote have been used to good advantage in countries like India; while in other countries special kinds of wood such as lignum-vitæ or camphor wood have been tried out with excellent results. This problem has also been met in some places by the introduction of steel ties. Thus on the Government railway system in Cape Colony 700,000 of these ties [20] have been used and have given much satisfaction.

In the United States the tie problem is also a big one; for as our forests are fast being depleted, we find good ties becoming very scarce and also very high in price. Thus the railroads realize that they must adopt a policy of conservation and use every effort to increase the life of the tie. While the ties used by the United States railroads have a longer period of usefulness—the average ranging from about 3 years for hemlock to 15 years for the redwoods—experts are trying to add to their life's span. Experiments have proven that in order to do so the wood must be subjected to processes that will overcome the effects of moisture. These processes consist of treating the wood with various solutions, such as zinc chloride and zinc creosote. Large and expensive plants have been erected by the various railroads for this purpose. The Chicago & North Western Railway, for example, has two such plants devoted exclusively to the treatment of ties. "One of these has a capacity of 800,000 ties per annum and the other of 600,000; the timber being of pine, spuce or fir. In the more recent plant at Riverton, Wyo., the retort is 6 feet in diameter with a track of 24½ inch gage, admitting at one time a train of 16 cars each containing from 30 to 32 ties * * *. With four charges in 24 hours, the average output is about 50,000 ties per month." [21]

As to the results which this process achieves, the following quotation from Prior's *Manual* gives us much enlightment, "The Atchison, Topeka & Santa Fe Railway officials, after more than 15 years' trial on a large scale, believe they are getting from 11 to 12 years service from mountain pine having a natural life of about 4 years, while from natural (untreated) white oak they get but 6 years in heavy main line service and from cedar 10 years under light service." [22]

Steel ties have been but little used as substitutes for wood in the United States. The only road using them to any extent is the Bessemer and Lake Erie where up to 1913, 850,000 of them [23] had been put into service. To protect these ties from weathering, a coat of hot tar is given them before they are placed in the roadbed.

Precipitation also has some marked effects upon rolling stock. The slippery condition of the rails brought about by the effects of rain, sleet, and snow greatly impairs train efficiency and necessitates the use of sand in large quantities. Under such conditions locomotive tires become worn very quickly and their period of usefulness is greatly reduced.

Droughts are also a source of worry to the railroad man. In the United States, in extremely dry seasons many fires along railroad right of way are kindled by sparks from locomotives, and thousands of acres of valuable timber are destroyed in this fashion each year. Dry seasons also have their effects upon railroads which depend upon hydroelectric power for their operation. Thus in the dry season of 1920 many electrified lines in California were obliged to curtail operations on this account. In the Tropics, dry seasons disturb railroad operation by their effects upon woodwork. Ties, both treated and untreated, which have withstood the previous rainy seasons often become splintered and wither away under the hot tropical sun.

We have already noticed how wind by causing snow to drift has become a factor for evil in railroading and we have seen the measures which have been adopted by various railroads in combating the same. When we turn to roads that pass through desert or sandy regions, we find similar obstacles in the shape of drifting sand to overcome. In the United States, railroads that are forced to follow the sandy shore line or river valleys have this problem to struggle with. Trees have been planted, board fences have been erected, and other methods similar to those used in handling drifting snow have been devised. Thus on the California coast the Southern Pacific Co. is waging a successful warfare against this problem by planting acacia trees and a coarse stout beach grass similar to that used on the dikes in Holland.[24] This plan has been followed by the Canadian Pacific along sandy portions of its line, while other railroads, especially those in the Columbia River Valley, have resorted to the board fence as a means of checking the depredations of the drifting dunes.

Wind velocities also have to be taken into consideration by the structural engineer when he thinks of steel bridges, and the effects of wind resistance must be calculated by yardmasters when making up their trains on days when gales are blowing.

Railroad accidents are often caused by heavy winds, and service is sometimes suspended when the gale attains high velocities. Thus in Ireland on the West Claire Railway, a narrow gage road running from Ennis to Kilkee, heavy westerly gales have often derailed trains. At first, the engineers tried to break the force of the wind by building banks on the windward side of the road, but these proved of no avail. "Finally a pressure-tube anemometer was installed to give warning of winds of dangerous velocity by ringing a bell in the station master's house. Two warnings are given; the first when the instrument indicates 65 miles an hour and the second when the velocity rises to 85 miles an hour. When the first warning has been given, 2,400 weight of movable ballast, kept for the purpose at every station, are put on each car of the train, this being amply sufficient to prevent an overturn. If the second warning comes, the trains are stopped until the storm abates."[25] Such accidents sometimes occur in the United States although nowadays with the heavy equipment they are very rare. However in September, 1921, at Sioux Falls, S. D., a thundersquall blew a train of about 50 empty stock cars from the track.[26] (See figure 1.)

[19] R. M. Brown: Climatic Factors in Railroad Construction and operation, *Journal of Geography*, April, 1903, p. 229.
[20] H. S. Haines: Efficient Railway Operation, p. 229.
[21] H. S. Haines: Efficient Railway Operation, p. 223.
[22] F. J. Prior: Construction and Maintenance of Railway Roadbed and Track, pp. 265-266.
[23] H. S. Haines: Efficient Railway Operation, p. 229.

[24] U. S. Geological Survey Bulletin No. 614, pp. 110-111.
[25] *Symons's Meteorological Magazine*, March, 1916.
[26] Information furnished by C. F. Allen, traveling salesman for the Dymond Simmons Hardware Co., an eyewitness.

THE TRANSPORTATION OF PERISHABLE GOODS.

No discussion of the weather element in transportation would be complete without a word about the handling of perishable freight. Since a large bulk of our staple food products are classified under this head, this problem has vital interest for each and every one. Goods of a perishable nature are very susceptible to damage through temperature changes. To guard against such damage and to keep the goods in a salable condition are duties that belong to refrigerator-car companies, fast-produce express lines, and railroad freight-traffic departments. This burden of responsibility which rests upon their shoulders becomes very great because of the flitting fancies of the weather and the sudden changes of temperature.

In an attempt to overcome these conditions, and thus increase their efficiency in the transportation of perishables, railroads have built and equipped large and expensive icing plants at all the principal terminal and junction points in the country. These plants are so located that whenever a car needs icing it can be switched to one of them and have its bunkers filled very quickly. Besides icing plants, many railroads, particularly in fruit-growing districts, own large precooling stations. Such plants have been erected by the Southern Pacific Co. at Roseville and Colton, Calif. We shall soon see how precooling greatly increases the efficiency of the refrigerator car.

The transportation of perishable goods also involves large investments in refrigerator cars. There are in the United States about 140,000 refrigerator cars,[27] most of which are owned by private car companies. These companies are controlled largely by the packing and fruit-growing interests. The cars themselves are well made and will safely transport goods even at low temperatures. "The better class of refrigerator cars will carry all perishable goods safely through temperatures as low as 20° (F.) below zero provided they are not subject to such temperatures longer than three or four days at a time."[28] With ordinary refrigerator cars, which are not so well constructed, a temperature of zero is considered the danger point for most perishable goods.

Some cars of the ordinary box-car type have been lined with matched boards and provided with heaters. These cars are known as heater cars and are considered especially well adapted to the shipment of potatoes in the fall and winter months. Goods shipped in these cars will stand an outside temperature of 20° below zero when a man is in charge to keep up the fires.

Cars with ventilated doors are quite commonly used by the market gardeners in the southern United States during the spring and summer months for the shipment of vegetables.

Sometimes during car shortages perishable goods are shipped in ordinary box cars. These cars are lined with paper and the goods are packed in straw or sawdust. Experience has generally shown that goods shipped in this way have reached destination safely as long as the outside air temperature remained between 20 and 50°. Because of the great risks involved, however, the practice of using these cars for such shipments is not generally recommended.

From the above statements we can see that railroads and refrigerator car companies have large sums of money invested in various types of equipment which are designed to protect perishable goods in transit. We shall now consider the transportation of some of these goods and see why this investment has been rendered necessary.

The packing, the dairy, the market-gardening, and the fruit-growing industries of the United States are especially dependent upon the railroads for their existence. The products of these various industries can find suitable markets only by being transported long distances in refrigerator cars, and their salability at destination depends largely upon the care given them in transit by the railroad men. Thus these various interests and the railroads are inseparably linked together.

In shipping fresh meats, the almost universal practice of the packers is to use refrigerator cars in which the temperature can be maintained at any desired degree. Fresh beef before shipping is usually chilled to a temperature of from 36 to 40° and then loaded into cars which have the same temperature as the chill room. When these cars are traveling long distances, especially in summer it often becomes necessary to re-ice them, the frequency depending on the prevailing temperature. Pork is more quickly injured by high temperatures than the other meats and hence requires greater care in shipping. Poultry in car-load lots is shipped in much the same way as fresh meat, while smaller shipments are made in containers which are covered with chipped ice and burlap. When the ice bunkers remain empty for any length of time, the temperature within the car rises, and this has a very deleterious effect upon the contents. During the writer's service as a claim inspector for a leading transportation company he was called in on several occasions to view beef cars that had been under insufficient refrigeration while in transit. The effects were always quite visible—bluish spots and mold could be seen on nearly every carcass in such cars. This meat could not find ready sale in the market and for the losses sustained thereon the railroad because of its failure to ice the car properly was always held responsible.

Fish are shipped from the various seaports by express and also by freight. When shipped by express they are packed in barrels with ice. Less-than-carload lots by freight are shipped in a similar manner, while carload lots are packed in bins built in the car and are thoroughly iced. Fish keep best while in transit at a temperature of about that of melting ice and hence for successful shipment this factor must be watched closely.

Dairy products also need careful attention while on the road. These products are usually handled in an expeditious manner by the roads which pass through the dairy sections of the Middle West, fast freight refrigerator service being regularly operated between these places and the eastern markets. Extremes of heat and cold are very injurious to cheese, while butter is seriously affected by being exposed to high temperatures. Proper refrigeration and the maintenance of a fairly stable temperature within the car are therefore very necessary if these shipments are to reach destination in first-class shape. Similar standards are also set for the proper handling of eggs and milk.

Potatoes are usually shipped in heater cars and are almost always accompanied by an attendant who looks after the fire. The stove is usually located in the center of the car between the doors and from this point the heated air flows out in all directions. Since these cars are very often improperly loaded and lined, the flow of heat is interfered with and the potatoes are often frozen. Investigations conducted by the United

[27] *Railway Mechanical Engineer*, August, 1919, p. 482.
[28] *U. S. D. A., Farmer's Bulletin 125*, p. 8.

FIG. 1.—Train overturned by squall at Sioux Falls, S. Dak., September, 1921.

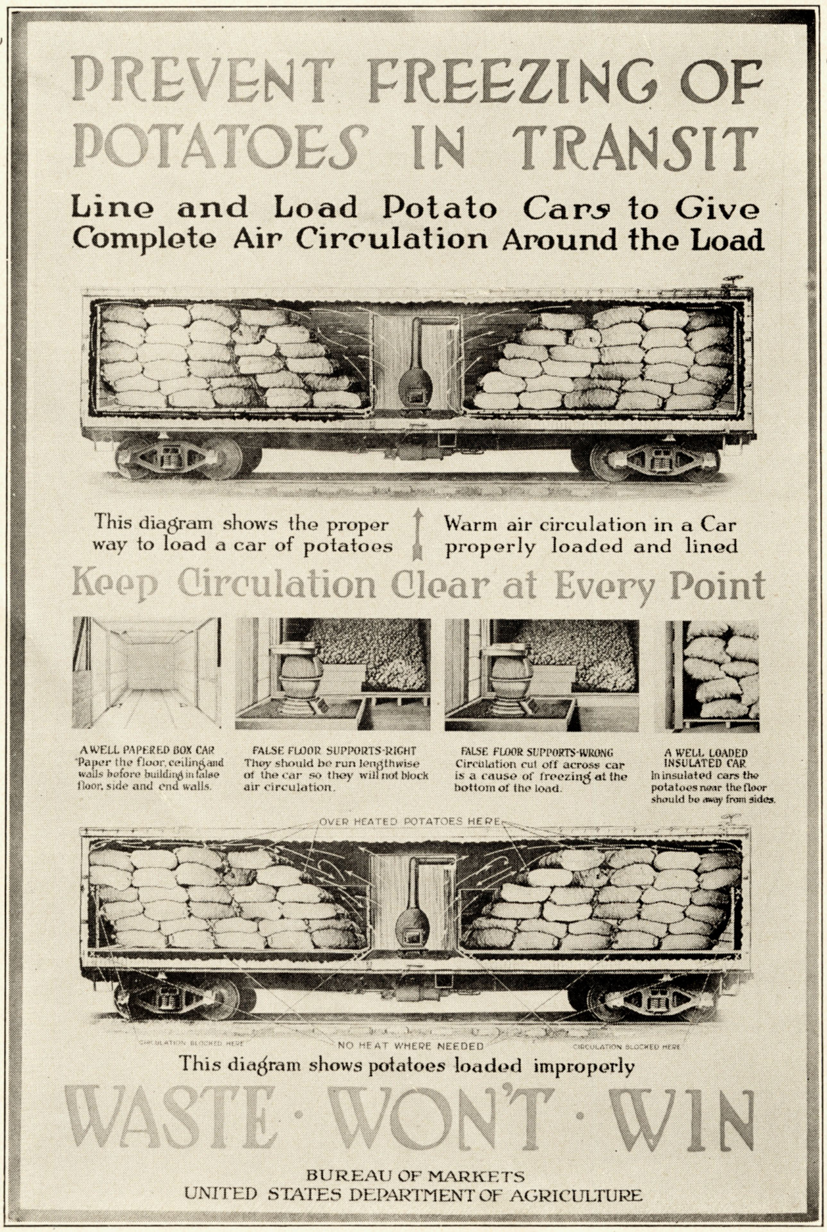

FIG. 2.—Bureau of Markets poster on proper loading of potatoes for shipment.

States Department of Agriculture showed that only one car in every four cars inspected was "so lined and loaded that the heater could properly protect the car even under ideal firing conditions."[29] The Government therefore recommends that this appalling situation be corrected by so lining and loading the cars that the warm air can circulate throughout the car and give an uniform temperature to the entire load. Figure 2 illustrates the correct methods they use in securing the above-mentioned conditions.

The citrus-fruit crop of California is one of the most important "perishables" that the railroads have to handle. Two methods are used in protecting these shipments while in transit—standard refrigeration and precooling. In the former, the fruit after being picked is carefully sorted and packed and then "loaded into a refrigerator car before either the fruit or the car has been artificially cooled, the boxes being so packed as to allow a free circulation of air between and around them. When shipments originate in southern California after being loaded, the car is usually taken to some assembling point, usually San Bernardino on the line of the Santa Fe or Colton on the line of the Southern Pacific and the bunkers are there filled with ice. As the car moves east the bunkers are opened from time to time and replenished with ice."[30] Experiments conducted with these cars have shown that during the first few days of the trip while the car is cooling down, the high temperature and great moisture often produce conditions which hasten ripening and decay. As a result of these investigations precooling was introduced. This system of refrigeration consists of preicing a refrigerator car—that is, "icing the car before loading or cooling the fruit before loading and loading into a preiced car."[30] Both carriers and shippers practice different methods of precooling; the essential difference being that in the former no attempt to cool the fruit is made until after it has been placed in the car. It has been found that cars shipped under this system require but little attention as regards icing in transit; in fact some cars have been known to make the trip from coast to coast without having their ice bunkers replenished. This saving of heavy icing bills and the better condition of the fruit upon arrival at destination seem to be the chief reasons for the adoption of this method by some of the orange growers.

Orange cars are equipped with ventilators which can be opened and closed at will. On the long trip across the continent, the position of these ventilators has to be changed several times to conform to the demands of the various climates through which the car must pass. This duty along with many others of a similar nature falls upon the train crew to whose charge the refrigerator cars are entrusted and it is to their zeal and efficiency that we owe the safe transportation of our orange crop.

The transportation of the other fruit and vegetable crops of the country from distant producing points to the large centers of consumption is also very interesting. The United States Department of Agriculture has conducted very thorough experiments in the shipping of many of these fruits and vegetables and the results which they have obtained therefrom give us much valuable information upon this subject. From these various investigations, we learn that the so-called summer fruits—the peach, the cherry, the plum, and the strawberry—are more subject to injury in transportation than are the fall and winter fruits. Hence it comes about that the railroads are handling these tender fruits with great care and dispatch. To give them quick movement to distant markets, special, through trains are often run from the growing regions to distant junction points, the Ozark strawberry specials of the Frisco lines being a particularly striking example.

Time will not permit us to go into the transportation of each of these various crops in detail. Suffice it to say, however, that you enjoy peaches from the orchards of Georgia, tomatoes from the far-away plains of Texas and strawberries from distant Louisiana as well as many another fruit and garden delicacy only because an efficient refrigeration service makes their transportation possible. In order to maintain this service at its highest efficiency the railroads often have to call upon the Weather Bureau for advice in regard to dangerous temperatures. When reports from the Weather Bureau indicate that perishable shipments already in, or traveling toward, a certain region are in danger, orders to protect them are forwarded to the railroad men in that district. When such orders are received, the men sally forth to protect the freight and to battle with the adverse weather conditions and so in the final analysis we see that the efficiency of the railroads in their struggle against the weather elements depends not only upon their wonderful equipment and roadbed but also upon the loyalty and cooperation of their employees whom we term "the railroad men."

CONCLUSIONS.

From the above discussion we can draw many interesting and helpful conclusions. First of all, we see that railroading the world over involves the waging of a constant and costly battle against the weather elements. Of these elements, temperature, precipitation, and wind have particularly destructive effects upon roadbed and rolling stock. To overcome these effects we find that railroads have to spend large sums of money not only for equipment to carry on the battle but also for materials to repair the damages to the shattered battle-ground. As these expenditures amount to millions of dollars annually, it can be seen that the railroads pay dearly for their victory—yet a victory which means much to the life of the world.

We also note that our present complex civilization demands of the railroads certain special equipment by means of which perishable foodstuffs can be brought in a safe manner from distant producing regions to the great centers of consumption. This also involves the expenditure of millions of dollars which we may term as the cost of armor plate used in the protection of perishable goods against that all-important weather element, temperature.

And yet in spite of these terrible costs the battle goes on; no truce has ever been declared or ever will be, for fate has decreed the battle of the railroads with nature a perpetual one.

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[29] *U. S. D. A. Farmer's Bulletin 1091*, p. 3.
[30] The Traffic Library, *Special Freight Services*, pt. 3, p. 119.